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LUMINARY Memo #216

To: Distribution
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Date: 23 April 1971
Subject: Impact of PCR 1107 (Abort Bit Backup) on Apollo 15 Abort Procedures

The implementation of PCR 1107 in the LUMINARY 1E flight program makes it easily possible to desensitize the LGC to the status of the abort (bit 1 of channel 30) and abort stage (bit 4 of channel 30) discretes. This is accomplished by setting bit 1 of the new pad-loaded erasable CHANBKUP, and has an effect equivalent to what was achieved in Apollo 14 through a lengthy sequence of DSKY keystrokes. The result of this action is that the LGC is totally non-reactive to the two abort buttons and thus the P70 and P71 programs can be activated only by means of the V37 routine. The purpose of this memo is to discuss the problems created by the use of this method for abort program selection, and to propose a particular procedure for use in subsequent Apollo flights if this type of discrete failure protection is implemented.

Even with bit 1 of CHANBKUP set, selection of an LGC abort program still requires the depression of the appropriate abort button at some point in the procedure. In the case of a DPS abort this will alert the AGS to the need for calculation of abort steering signals. In an APS abort the abort stage button also causes an indication to be sent to the AGS but additionally triggers a sequence of hardware activities that culminates in vehicle staging and ignition of the ascent engine.

If the abort bits are to be ignored by the LGC, the various overall procedures that could be used to enter P70 and P71 are numerous. Some of the factors to be considered in the selection of a procedure are the role of the AGS, the degree of manual attitude control required (if any), and whether the abort/abort stage pushbutton is depressed before or after the V37 selection

of P70/P71. In the studies leading to this memo, however, no procedures were examined that required an operational AGS. This is because of the fact that an operational AGS may not always be a necessary condition for a lunar landing. And in any event PCR 1107 affects only the PGNCS -- in the AGS the two abort discretes continue to be monitored.

A wide variety of possible abort procedures have been examined over the past few weeks and have been subjected to both hybrid and digital simulation. At the current time only one technique appears to be satisfactory from the standpoint of simplicity and universality:

1) Depress abort or abort stage pushbutton
2) Key in V37E70E or V37E71E as soon as possible.

It is assumed in this procedure that the LGC is in PGNCS - AUTO. A complicating factor is the possibility of a hardware restart following the switch from Descent to Ascent batteries upon depression of the abort stage button. If the restart light appears on the DSKY during the entry of keystrokes it will be necessary to re-initiate the sequence. Once the final ENTER has been keyed and the appropriate major mode number has appeared on the DSKY the LGC abort programs are fully restart protected. It should be noted that this abort procedure duplicates very closely the mode of program operation when the abort discretes are not ignored by the LGC. The major difference is that of elapsed time between the depression of the buttons and the initiation of abort program computations. When R11 is the agent that selects an abort program this time lapse is less than perhaps .3 seconds. With the above technique the time lapse is a function of the speed with which the keystrokes are entered and is bound to be at least four or five seconds at a minimum. Much of the time spent on investigation of this technique has been in analysis of the consequences of this increased time lag and, in addition, examining the behavior of the LGC if the lag is much greater than four or five seconds.

On the premise that the LGC is to be left in control of the vehicle during the course of the recommended procedure, three digital simulations were made in which the time interval between steps 1 and 2 was thirty seconds during APS aborts. The abort stage button was depressed and the LGC was left in control of the current guidance program (P63, P64, and P66) for thirty seconds before P71 was finally selected. The results were pleasant. Aside from substantially increased RCS fuel consumption and larger than normal attitude rates and errors, both the guidance and control loops were stable. In P63 and P64 the effect of the lower acceleration provided by the APS engine caused one-shot attitude changes of a few degrees but the landing continued in a more or less normal fashion. The only error condition that arises from this prolonged lapse in time is the single 511 alarm that R12 initiates when it is deprived of a radar antenna. In P66 the guidance performance is acceptable and predictable although far from nominal. The reason for this is that the fixed ascent engine thrust level is approximately twice that desired by the vertical velocity control channel of P66. Despite assiduous attempts by the vertical channel to reduce thrust, the LM accelerates vertically. The horizontal channel, however, continues to null the forward and lateral velocity components during the course of this ascent.

During the interval between the staging of the LM and the start of P71, the autopilot controls the ascent stage as though the descent stage were still attached. The very large errors in the assumed RCS and GTS control-authorities lead to errors in the estimates of angular rate and angular acceleration. However, the control is not as bad as might be expected for two reasons. First, and most important, the knowledge of the attitude errors is not affected by the misestimated control authorities, and the RCS control laws will not allow the attitude errors to go more than a few degrees beyond the deadband. Secondly, the rate estimator is very fast; i.e. it corrects errors rapidly on the basis of measured attitude (CDU) changes. Thus, in the three test runs, the attitude errors were kept quite small. There was a great deal of extra RCS firings, but fuel economy would not appear to be a problem over the length of time that is being considered here.

At this point in time there are three remaining questions to be answered regarding this recommended procedure:

a) What are the consequences of the time lag between steps 1) and 2) in very early aborts or in late aborts? In an early abort case if the vehicle had begun to spin and was thrusting posigrade at the time of abort program selection it appears that there is a possiblity of over-burn. In a substantially over-burned case the consequent behavior of the ascent guidance equations has not as yet been thoroughly studied. The effects of delaying pitchover, however, in a late abort have been analyzed by Larry Berman in LUMINARY Memo #212 and appear to be entirely acceptable. A delta-V penalty is incurred, but even a tipover delay of 24 seconds would be within the nominal ascent propellant margin.

b) To what extent might manual attitude control be desirable while the DSKY keystrokes are being inserted? Regardless of whether the abort occurs early or late in the landing the only case that would seem to require immediate manual override would be if an APS abort was being instigated because of vehicle spin resulting from, possibly, a runaway engine gimbal. In this instance it might be advisable for the astronaut to depress the abort stage pushbutton and to stabilize the vehicle while the DSKY activity is in progress. This would require switching to attitude-hold and then coping with the V50N25 display (R1=203) that the abort programs would put up as a consequence. It would then be requisite to return control to the LGC within a reasonable length of time unless the astronaut had been obeying the ascent steering signals through the process of nulling the attitude error needles.

c) Would there be any control problems if the abort occurred with the heaviest unstaged vehicle possible (i. e. extremely early in the descent) and/or if a rapid PGNCS manual maneuver were called for between staging and the entry into P71? No real difficulties are anticipated, but a little testing is indicated.